

HIGH SOLIDS COATINGS FOR DAMP SURFACES

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OVERVIEW

The Corps of Engineers is responsible for maintaining many steel structures subjected to conditions of constant condensation. Many of these structures are located inside locks and dams. Examples include gates, reservoir outlets and their gate recesses, piping systems inside dams, and valves on locks that are difficult to remove from their recesses. The standard paint system for these surfaces is a solution vinyl paint system. This paint system, when properly applied, provides many years of corrosion protection.

A problem with this system, however, is that its high solvent content conflicts with some state and local air pollution regulations. Another problem is that there are tight requirements for surface preparation when using this system. The surfaces must be blast-cleaned to a white metal grade. Condensation or spray in these environments often require the contractor to take extreme measures to eliminate water flow and reduce the humidity.

The coatings industry has recently begun to produce high solids coatings that are advertised to be capable of providing acceptable adhesion to damp and wet steel and to provide a high level of corrosion protection. The objective of this work was to evaluate high solids proprietary coatings developed and marketed for application to damp or wet steel surfaces and develop a performance specification for civil works applications.

The research was conducted in three phases. In Phase I various proprietary coatings were obtained and tested to determine test methods that would properly simulate the conditions experienced in the field. Phase II evaluated a larger number of coatings using test methods that would more clearly identify superior products. In Phase III, the most promising coatings were applied to field structures in order to validate the laboratory test results. Based on the findings of this work, test methods were modified and a draft Commercial Item Description (CID) was prepared. Five materials were tested according to the draft CID; three of

these were found to meet all the requirements and were included in the CID as potential sources of supply.

PHASE I RESEARCH

Candidate coatings for the research were obtained by contacting companies listed in the *Annual Directory of Coatings, Linings, and Floor Toppings*. Eight coatings were selected for Phase I. All coatings were applied to sandblasted steel panels. The panels were divided into three sets: dry, damp, and wet. The dry set of panels had no further treatment before application of the coating system. The damp panels were coated in a cool, high-humidity environment. The wet panels were wetted with distilled water during application. All coatings were brush applied. The 3 sets of panels were subdivided into 3 exposure conditions (dry, damp, and condensation). The coatings were allowed to cure in the exposure environment for 7 days before performing adhesion and solvent (MEK) resistance testing. In addition to these formal tests, each coating was subjectively evaluated for any other characteristics that might be of significance in the anticipated field application. These characteristics included mixing and application properties, pinholes, craters, or other defects in the applied coatings, and any effect that might be attributed to the damp or wet application conditions.

PHASE I RESULTS

No differences could be detected in the ease of applying any of the coatings to cool, damp surfaces versus dry surfaces. In all cases, however, application of the coatings to wet surfaces was difficult. All the coatings tended to crawl or crater during the initial brush stroke, and many strokes were needed to spread the coatings over a wet surface.

Craters or other defects appeared in the films of some of the coatings soon after application, but no relationships were found between defect formation and the condition of the panel (i.e., dry, damp, or wet). Therefore, it appeared for these coatings that the defects were related to the film-forming properties of the coating materials rather than to panel condition.

The performance results for the coatings in the adhesion and MEK resistance tests (after curing for 7 days in the three environments) showed that most coatings exhibited either *no* effect or a *major* effect, but rarely a *moderate* effect.

Few coatings resulted in any detectable differences in

adhesion or MEK resistance when applied to cool, damp, or dry surfaces and dried in ambient laboratory conditions. Similarly, only a limited number of coatings exhibited a difference in performance when cured in dry or damp environments. However, a significant number of coatings were adversely affected by curing in the condensation environment produced in the condensation chamber. Only 2 of the 8 coatings showed no noticeable effects from any of the exposure conditions.

PHASE I CONCLUSIONS

Phase I demonstrated that there are coatings available that will adhere to wet steel in a condensing environment. The most demanding condition in the work performed required the coating to cure in a condensing environment. Curing in a low-temperature, high-humidity environment had little if any effect on most of the coatings. Therefore, it was decided that Phase II work should concentrate on further identifying the coatings that exhibited suitable performance when applied to wet panels and cured in a condensing environment.

PHASE II RESEARCH

The objective of Phase II was to further define the test methods and evaluate additional coatings. Spray application of the coatings and two-coat systems were added to the testing matrix. The specific coatings tested were chosen by the manufacturers themselves knowing the conditions under which the coatings were to be applied and to which they would be exposed immediately after application. Each manufacturer also recommended the film thickness and the number of coats to be applied. The systems tested are shown in Table 1.

Twelve coating systems were obtained for application and evaluation. Two of the coatings were the better-performing coatings from Phase I. Evaluation focused on the application characteristics and resistance to immersion or condensation conditions immediately after application. The coating systems were applied to white-metal-blast-cleaned carbon steel test panels that were wetted with fresh tap water. The coatings were applied either by brush or an airless spray system. Immediately after application the panels were placed either in distilled water or in a condensing humidity cabinet. After 2 weeks of exposure, the panels were evaluated for the following properties: adhesion, MEK resistance, blistering, and loss of adhesion at the scribe.

PHASE II RESULTS

After all of the data were collected, the results for each paint system were reviewed to determine if the system might be acceptable for use in field conditions. The coatings that performed well were systems 8 and 12. These systems had the best final testing results, with excellent adhesion, no blistering, and slight to no color transfer during MEK resistance testing. These same panels showed no loss of adhesion at the scribe.

Coating systems 4, 10, and 11 also had excellent adhesion, no blistering, and no loss of adhesion at the scribe but had slight to high color transfer during the MEK resistance testing. System 5 also had impressive performance properties, but was not included among the highest performers because of its poor application properties.

PHASE II CONCLUSIONS

Analysis of the test data clearly separated the coatings into three distinct performance categories: the best (two products); the middle (four products); and the poorest (six products). Because the tests clearly discriminated coatings on the basis of performance, it is concluded that the test methodology was appropriate for laboratory screening purposes.

PHASE III FIELD APPLICATION

A contract was awarded for the application of 2 systems to 2 outlet gates at a Corps of Engineers reservoir. The paint application requirements called for a "stripe" coat -- preliminary coat applied by brush to edges, corners, bolts, and other surface irregularities. The stripe coat was to be followed as quickly as possible by the application of the first coat of the paint system. Paint on all vertical and overhead surfaces was to be applied by airless spray. If excess moisture had condensed on these surfaces, they were to be wiped with clean rags before application of the coating. The floor of the structure was expected to be wet due to incomplete seal of the bulkhead. On this area the paint was to be applied with a roller; the area was to be rolled and backrolled in an effort to displace any standing or flowing water. Subsequent coats did not require the stripe coat. A target dry film thickness of 15 mils was required. Any areas with a measured coating thickness of less than 12 mils would require additional paint.

Gate 1 was to be painted with Reactic 1208 (gray), manufactured by the Imperial Division of Carboline. This material was referred to Coating 2 in the Phase II study. It performed well in the Phase I study but exhibited blistering under the exposure conditions used in the Phase II study. Reactic 1208 was included in the Phase III study to determine whether successful field application necessarily required a coating with superior laboratory results. The manufacturer offered assurances that the product would perform satisfactorily in the actual field environment, and indicated that this coating is routinely applied without thinning, using brush, roller, or airless spray. The manufacturer stated that wet film thicknesses in excess of 10 mils would probably result in sagging.

Application conditions at Gate 1 were high humidity and temperatures in the 50 to 52 °F range. Sagging created major difficulties, and long cure times created delays in the operation. Because the wet film thickness was well below the manufacturer's specified 10 mil sagging point the contractor sought additional guidance from the manufacturer. The manufacturer stated that although the application was within the temperature and humidity limits indicated in the company literature, the company had no actual field application experience under these conditions. In order to complete the application, the contractor was allowed to apply a significant amount of the coating by brush. The separate stripe coat required by the contract was not applied.

The application to Gate 2 was at the same location as Gate 1, but the contractor was allowed to raise the temperature to approximately 68 °F. Application was by airless spray as required by the contract. The paint system was Permax 9043 Type I wet process epoxy (gray), manufactured by Engineered Chemical Coatings. This material was referred to as Coating 8 in the Phase II study. It was selected because of its high performance in the Phase II study. The manufacturer indicated that 10 percent thinning was usually necessary for airless spray, but thinning was usually not necessary for brush or roller application. Sagging could be expected at wet film thicknesses greater than 9 to 10 mils. Dry film thicknesses in excess of 12 mils per coat could create stresses within the coating and should be avoided. Product literature warned that lower temperatures and increased film thicknesses increase the dry-to-topcoat times published in the technical data sheet.

After being painted, both gates were returned to service, which included either hanging in a high-humidity environment or being immersed in fresh water. The first inspection was conducted after approximately 2 years of service. At that time Gate 1 had many areas of rust visible on complex areas of the gate. If the stripe coat had been applied as required by the contract, many of these coating failures would have been

avoided. Some areas of relatively intact coating were found to be blistered. It was typical to find blistering in areas where the coating thickness exceeded 20 mils. In areas where the coating was 12 to 16 mils, the coating had smaller blisters. Little blistering was noted in areas of less than 10 mils thickness.

After 2 years of service, the coating on Gate 2 had excellent adhesion and no blistering. The coating was well applied to corners and rivets, and very little rust was noted in these areas. Coating thickness ranged from 10 to 12 mils on the structural side of the gate and 18 to 20 mils on the smooth side. The gate was covered with a thick layer of black scum that was not noted on Gate 1. The scum was not identified, but it appeared to cause no adverse effect to the coating or to the operation of the structure.

A second contract was awarded to apply the same coatings to an outlet structure. The structure to be coated consisted of two conduit liners extending through both the emergency gate and service gate areas. The total area of each liner was 430 sq ft. Service gate liner walls and ceiling were heavily rust-pitted and blistered in areas. Epoxy patch had been used to fill in the more heavily pitted areas. Seams, edges, and areas of seepage or weeping had created calcium deposits on the walls and ceiling of the liners. The liner walls and ceiling were damp or wet in areas of weeping. Water on the floor averaged 1.5 to 2 in. deep.

Work was conducted on the west conduit liner in late November. Water leaking around the gate created quick flash rusting after sand blasting. Several products were used in attempts to reduce the leakage but were unsuccessful. Severe flash rusting was reblasted before painting. All old paint and corrosion products were removed to SSPC SP5 specifications but, by the time the paint could be applied, the steel had changed color from white metal to a dark gray on most walls, and black on the floor.

The west conduit area was coated with Reactic 1208. The paint was mixed according to the manufacturer's instructions. Thinning varied from 10% to 20%. The paint was applied to wall and ceiling areas using conventional spray equipment. It was found that a wet film thickness of 8 mils could be applied on walls and ceiling without sagging. An attempt to apply >12 mils in a single coat resulted in considerable sagging. Sags were sanded to a 5 to 8 mils thickness and the remainder of the coating thickness applied with rollers. The paint was hard to roll and adhere because of the moisture on the walls. Application to the floor area could not be accomplished by spray because of the flowing water, so the coating was simply poured onto the floor and spread with a roller. Hard pressure was required against the roller to get adhesion of the paint

on the floor. The small area along the wall was coated using a brush. The on-site manufacturer's representative recommended a single 15 mil coating applied to the floor because long curing periods under water create difficulty in applying a second coat. According to the representative, the finish on the first coat would be too slick and hard for proper adhesion of the second coat. The dry film thickness varied from 12 to 20 mils on the walls and 16 to 30 mils on the floor.

The east conduit was sandblasted and painted in early December. The area was coated with Permox 9043. The paint was mixed according to the manufacturer's instructions, thinned approximately 15 percent, and applied with conventional spray to the ceiling and walls. The floor area was coated with roller and brush. There were a few seepage problems that resulted in pinholes in some small areas and adhesion failure in larger seepage areas. Pinholes were most common on the ceiling area. The dry film thicknesses varied from 13 to 20 mils on the walls and ceiling, and 20 to 40 mils on the floor.

After 9 months of service the performance of the coatings was observed. The Reactic in the west conduit was blistered in all areas. The only areas of rust were a 2 to 6 in. tall area extending several feet along the intersection of the floor with the wall (underwater application by brush) and a few areas of pinpoint rusting on the ceiling of the service liner.

After 9 months of service the Permox coating was found to be hard and no blistering was noted. There was a line of rust about 1 to 1.5 in. tall and extending for about 3 feet on each side of the liner where the floor and the wall meet. This area was brush-applied and may not have sufficient thickness. Actual thickness measurements could not be taken at the time of the inspection because the area was underwater. There was also a small amount of rust where the steel joined the concrete and minor pinpoint rusting on the ceiling. The remainder of the coating appeared durable and was providing complete protection.

A second inspection of both liners after 1.5 years indicated little change from the 9 month inspection.

PHASE III CONCLUSIONS

Several conclusions were drawn for this phase of the study:

1. The blistering noted with Reactic 1208 reinforced the Phase II test results, but also indicated that the failure was related to increased film thickness.

2. The good performance of the Permox 9043 also reinforced the Phase II test results.
3. The low temperatures in the conduit caused an increase in sagging, which should be addressed in any anticipated product specification.
4. Spray application was practical on vertical surfaces that were damp but where the water could flow off the surface.
5. Pinholes developed on the ceiling areas where water hung in droplets. Rolling or brushing may have been a more effective method of application in this area.
6. Products could be applied to floor areas that were underwater by using a roller in a single-coat application.
7. Application by brush may be the only practical method for applying a stripe coat, but should not be used for larger areas where rollers or spray equipment could be used to apply more uniform thicknesses.

CONCLUSIONS AND RECOMMENDATIONS

This research has shown that coatings are available that will adhere to an abrasive-blasted steel surface that is either damp or wet at the time of application. One such coating is continuing to provide a satisfactory level of corrosion protection on a gate after 2 years, and on a conduit liner after 1.5 years. However, this conclusion does not imply that the level of protection is equal to that of a high-performance coating applied under dry conditions. Even the best of the coatings tested allowed some rust to occur in areas where the coating was thin or its application did not completely displace the water. Therefore, it is recommended that these coatings only be specified in areas where it is not possible to achieve a completely dry surface.

The laboratory test methods used to evaluate the products provided an indication of potential performance, but results from the field applications indicated that some tests should be modified in order to identify specific problem areas:

1. In the field, application by roller appeared to be the most practical method in areas where surfaces had a significant amount of standing or running water. Therefore, laboratory testing should include roller application to wet panels.

2. The low temperatures encountered in the field application aggravated sagging problems and curing times. Therefore, laboratory application and cure testing should be conducted at a temperature similar to that encountered in the field. The lower-temperature test conditions will require lengthening the immersion testing in order that adhesion loss and blistering results may be observed.

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TABLE I. PHASE II COATINGS.

Sys	Number of Coats	Generic Paint Type	Dry Film Thickness (mils)	Mix Ratio	Volatile Organic Content	Cost/sq ft (2000 sq ft area)	Total System Cost/ft ²
1	2	primer- epoxy	4 - 8	4:1	2.4 lb/gal (292 g/l)	\$0.13	
		topcoat - epoxy	4 - 8	4:1	2.4 lb/gal (292 g/l)	<u>\$0.13</u>	\$0.26
2	1	high-solids epoxy	8 - 10	1:1	0.24 lb/gal (28.8 g/l)	\$0.25	\$0.25
3	1	polyamine-cured epoxy	8	1:1	1.3 lb/gal (156 g/l)	\$0.12	\$0.12
4	2	primer – polyamide – adduct cured epoxy	4	3:1	1.3 lb/gal (156 g/l)	\$0.12	
		topcoat – polyamine-cured epoxy	6	1:1	3.48 lb/gal (417 g/l)	<u>\$0.07</u>	\$0.19
5	2	primer – moisture-cured polyurethane	3 - 4	1 comp	2.8 lb/gal (336 g/l)	\$0.05	
		topcoat – moisture-cured polyurethane	3 - 4	1 comp	2.8 lb/gal (336 g/l)	<u>\$0.03*</u>	\$0.08
6	1	epoxy	4 - 8	4:1	2.4 lb/gal (292 g/l)	\$0.13	\$0.13
7	2	epoxy mastic	5 - 7	1:1	2.83 lb/gal (339 g/l)	\$0.09	
		urethane	1.5 - 2	1:4	3.48 lb/gal (417 g/l)**	<u>\$0.06</u>	\$0.15
8	2	glass-filled epoxy	5	1:1	0.93 lb/gal** (111 g/l)	\$0.165	
		glass-filled epoxy	5	1:1	0.93 lb/gal** (111 g/l)	<u>\$0.165</u>	\$0.33
9	2	epoxy/ amine-modified polyamide	3 - 8	1:1	2.1 lb/gal (252 g/l)	\$0.13	
		epoxy/ amine-modified polyamide	10 - 12	1:1	2.1 lb/gal (252 g/l)	<u>\$0.24</u>	\$0.37
10	1	epoxy copolymer	14 - 20		2.0 lb/gal (240 g/l)	\$0.82	\$0.82
11	2	epoxy	8 - 10	2.3:1	0	\$0.35	
		epoxy	8 - 10	2.3:1	0	<u>\$0.35</u>	\$0.70
12	1	amine-cured epoxy	20	4:1	1.47 lb/gal (176 g/l)	\$0.71	\$0.71